Development of Mid-Frequency Multibeam Sonar for Fisheries Applications

John K. Horne
University of Washington, School of Aquatic and Fishery Sciences
Box 355020
Seattle, WA 98195
phone: (206) 221-6890 fax: (206) 221-6939 email: jhorne@u.washington.edu

Christopher D. Jones and Michael A. Wolfson
Applied Physics Laboratory, University of Washington
Seattle, WA 98105
phone: (206) 543-1615 fax: (205) 543-6785 email: cjones@apl.washington.edu , wolfson@apl.washington.edu

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LONG-TERM GOALS

This program investigates the utility and methodologies of mid and higher (≥10 kHz) frequency acoustics to detect, enumerate, and identify pelagic fish distributions.

OBJECTIVES

Objectives of this research include: comparisons of fish backscatter models, models of mid-frequency sound propagation, development of a mid-frequency multibeam sonar, and backscatter measurements using splitbeam echosounders and the multibeam sonar.

APPROACH

Our strategy integrates biological and physical model predictions with field measurements and will combine results in statistical analyses, computer visualizations and animations. Efforts are directed in three primary areas: sound propagation modeling, fish backscatter modeling, and mid-frequency multibeam development and field measurements.

Sound propagation modeling efforts integrate realistic bottom substrate and fish densities to generate realistic scattering environments. Effects of multi-path propagation, water depth, substrate type, substrate and surface roughness, and range dependence on propagation, including temporal and spatial variability in the environment can be modeled. Sound propagation characteristics are combined with anatomical models of fish to examine backscatter from individuals and aggregations. This approach enables us to model potential detection strategies for different types of fish, their behaviors, and to predict variability in fish aggregation backscatter.

Fish backscatter modeling includes examining how fish biology (i.e. anatomy, behavior, physiology) interacts with the physics of sound propagation, and quantitative descriptions of fish distributions. Empirical data from NOAA-NMFS acoustic-trawl surveys in the northeast Pacific are used to provide information on fish packing density and three-dimensional distribution. Analytic techniques

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developed to describe walleye pollock distributions are generalized for any fish species in any environment.

To measure synoptic distributions of fish schools we collect mid (10 kHz) and high (38 kHz) backscatter data from fish aggregations using a multibeam sonar and a splitbeam echosounder. The sonar is expected to detect fish at kilometer scale ranges while the echosounder will be used to detect aggregations and individual animals at ranges of hundreds of meters.

WORK COMPLETED

Tasks completed during this reporting period included conducting an acoustic backscatter modeling workshop, finalizing the sound propagation and fish aggregation modeling package, publication of a manuscript on acoustic classification of fish aggregations, and completion of a draft manuscript on the influence of the environment on fish distribution patterns.

RESULTS

International researchers active in backscatter modeling of fish and zooplankton were invited to the University of Washington's Friday Harbor Laboratories to participate in a 3-day workshop. A total of 18 people participated in the workshop (2 virtual participants using streaming video and audio through the web) representing 9 different backscatter models and participants from 6 countries. Prior to the workshop, all participants were sent identical data files containing anatomical outlines and material properties of 2 fish and one zooplankton. The goal of the workshop was to compare and contrast approaches to backscatter modeling of aquatic organisms, and the resulting predicted target strengths of the fish and zooplankton as a function of length, frequency, and aspect angle.

Figure 1. Participants in the Acoustic Backscatter Modeling workshop.
Front row (l to r): K. Sawada, G. Macaulay, N. Gorska, D. Chu, M. Jech, R. Gamble;
Second row: S. Fassler, B. Reeder, B. Jones, T. Stanton, K. Foote;
Back row: R. Thomas, J. Horne, C. Clay, R. Francis, R. Kreisberg.

Nine backscatter models were presented at the workshop. Target strength predictions for Atlantic herring (Clupea harrengus) were more variable than anticipated. Lots of discussion ensued with the resulting suggestion that participants predict backscatter from geometric shapes with exact solutions and that these results would be compared in a future workshop. Participants are now predicting target strengths of a sphere, a prolate spheroid, a finite cylinder, and a spherical fluid shell. Results are being tabulated as they become available and will be compared at a future workshop. Three papers are planned from this effort: comparison of models and predictions using the standard shapes, target strength prediction comparison of Atlantic herring, target strength prediction of zooplankton. A draft of the standard targets paper has been completed.

The computer code for simulating the propagation of sound through a waveguide to measure backscatter from fish is complete. Waveguide propagation parameters are modeled after those used in the PIMS sonar. Integration of the sound propagation modeling package with the geostatistically-based fish aggregation simulator so that backscatter can be predicted from fish aggregations with known acoustic characteristics has been completed. Model structure and initial parameterization was presented at the joint ASA/ESA conference in Paris by M. Wolfson. An initial test of the simulation package will be the workshop problem proposed by Eric Thorsos and colleagues (ftp://ftp.ccs.nrl.navy.mil/pub/ram/RevModWkshp_II/Problem_F). This exercise is used to validate the modeling approach, corroborate model predictions with other model results, and provide a measure of confidence when modeling realistic fish aggregations. Results from an initial simulation (Fig. 2) show that even though a slower substrate (mud or clay) has approximately four times less absorption than a faster bottom (sand), the faster bottom included more multipath sound propagation and resulted in higher reflection (i.e. backscatter seen as a brighter image) in the lower right panel of Figure 2.

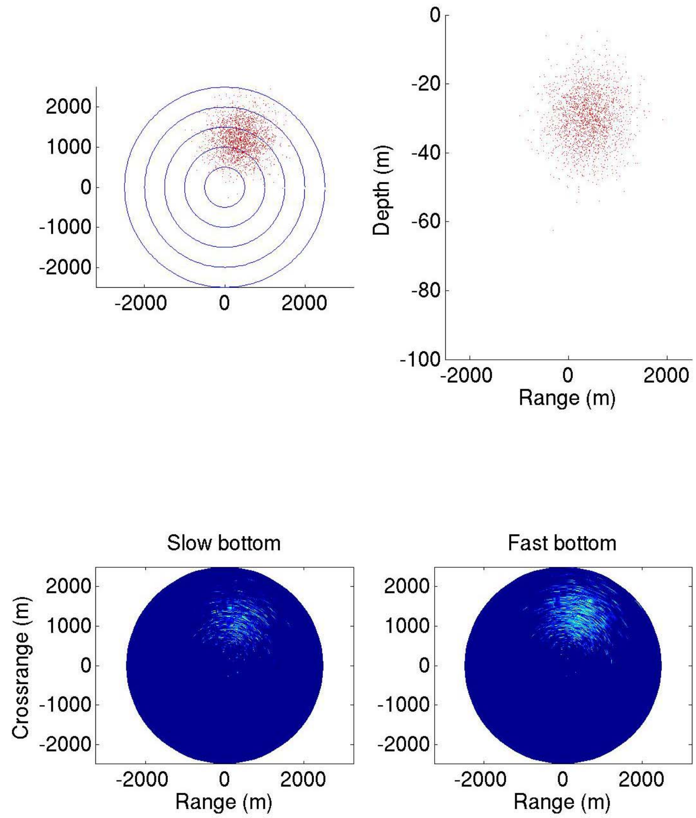

Figure 2. The top two panels illustrate a Gaussian 'cloud' of 2,000 fish located at 30 m depth (with ± 10 m depth standard deviation) and 400 m horizontally East and 1200 m North of the hypothetical location of the PIMMS sonar (origin in left upper panel and at a depth of 50 m in right upper panel). The model results are shown in the lower two panels for a slow muddy (left) and fast sandy (right) type of bottom.

Two backscatter modeling efforts have been completed in association with Julian Burgos' Ph.D. project: categorizing morphologies of fish aggregations using walleye pollock (*Theragra chalcogramma*), and correlations between fish aggregation metrics and environmental covariates in the Bering Sea. In the categorization paper, a series of 20 landscape metrics were calculated in 1 nautical mile transect segments to measure occupancy, patchiness, size distribution of patches, distances among patches, acoustic density, and vertical location and dispersion. Factor analysis indicated that the metric set could be reduced to four factors: spatial occupancy, aggregation, acoustic density, and vertical distribution. Cluster analysis was used to develop a 12-category classification typology for distribution patterns. Visual inspection of Figure 3 illustrates that spatial patterns of segments assigned to each type were consistent, but that considerable overlap existed among types.

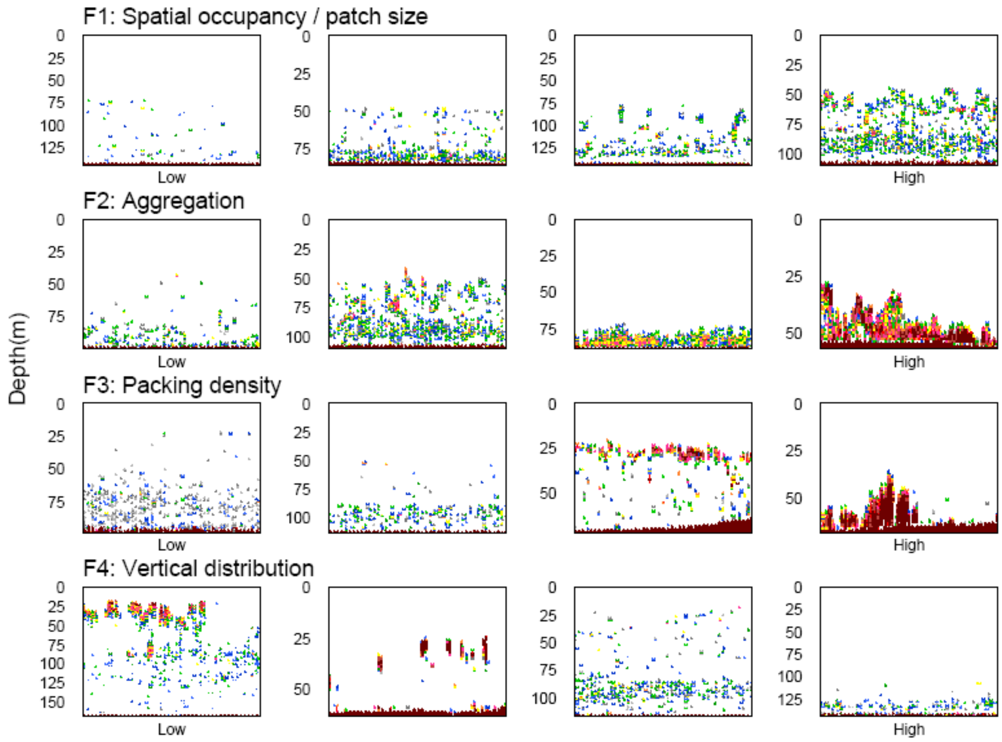

Figure 3. Sample echograms for the four factors (spatial occupancy, aggregation, packing density, vertical distribution) representing the range of factor scores. Echograms in each column correspond to a factor score approximately at each 25th percentile of the factor range.

Testing and deployment of the PIMS (Pelagic Imaging Multibeam Sonar) system have continued through 2008 with additional deployments planned for October 2008. In spring the system was deployed unsuccessfully in Monterey Bay from the RV Shana Rae due to electrical problem with the ship. The field deployent planned for October 08 will use the new APL-UW vessel RV Robertson in Puget Sound in coordination with Jan Newton's class at the UW Friday Harbor Labs (FHL). Testing of the sonar on the APL vessel is underway. At this time, no new field measurement results are reported.

IMPACT/APPLICATIONS

The integration of propagation and fish backscatter modeling suites provides a tool to investigate attributes and constraints of acoustic instrumentation. Backscatter simulations can be used to construct population distributions for sound propagation or survey design experiments. The imaging sonar may be used in conjunction with quantitative echosounders or in a moored deployment as part of an ocean observing system.

RELATED PROJECTS

The 2008 deployments of the multibeam sonar are coordinated and jointly supported with the NOPP sponsored project entitled, "Novel Acoustic Techniques to Measure Schooling in Pelagic Fish in the Context of an Operational Coastal Ocean Observatory."

PUBLICATIONS

Burgos, J.M. and J.K. Horne. 2008. Acoustic characterization and classification of pelagic organisms distributions. ICES Journal of Marine Science (doi: 10.1093/icesjms/fsn087) ICES Journal of Marine Science 65: 1235-1247.

Burgos, J.M. and J.K. Horne. Influence of the environment on distribution patterns of walleye pollock in the eastern Bering Sea shelf (in prep).

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